# UNDERWATER SEDIMENT MANAGEMENT

The present invention comprises to an apparatus for carrying out controlled excavation and movement of loose bed material in marine, river, lake and similar underwater environments. Modifying the underwater bed topography, by selective removal of bed material from one area and deposition in another, comes under the ambit of sediment management. The present apparatus is designed for sediment management operations, primarily, in shallow water (1-50m water-depth).

The herein-described apparatus incorporates an embodiment of a means for dredging, scouring, excavation and cleaning, described more particularly in PCT/GB2003/005030. In the latter document the embodiment, namely a ducted-propeller, is described in more detail, together with various alternative modes of operation and means of deployment. The herein-described apparatus can be seen as providing a suspended underwater vehicle deployment means, for bring to bear the operation of the ducted-propeller.

As such, the present invention is deployable in a similar manner to the Wing Dredger described in U.S. Patent No. 6125560, in terms of deployment from a floating vessel by means of suspension wires for the purpose of controlling the direction of the propeller jet(s) relative to the bed. A further similarity exists with the Wing Dredger in the design of the propeller and the duct, and in having the propeller mounted at the outlet end of the duct. However, the present invention differs from the Wing Dredger in being designed specifically for use in shallow water, in being more versatile in terms of single- and multiple-jet operation and in embracing a wholly new and novel approach to propeller jetting.

This new approach recognises and takes advantage of the fact that the jet created by the said ducted-propeller, is not simply a thrust means. Rather, it is a complex swirling flow, which includes a number of embedded vortical flow elements. The various ways in which the said swirling jet can be modified and can be used for

excavation and controlled movement of bed material are described, more particularly, in PCT/GB2003/005030. Suffice it to say, swirl imbues the jet with certain behavioural characteristics, which when properly directed can be highly beneficial for a range of sediment management operations.

In its broadest sense, the present invention provides an apparatus comprising a body having a bottom face and comprising an outlet flow path in which is mounted thrust means to direct, in use, a wash of water downwards towards an area of sea or river bed or the like, orientation means to connect said apparatus, in use, to a support means to orientate said apparatus with respect to the sea or river bed, and at least one inlet flow path through which water is supplied, in use, to the thrust means; characterised in that the inlet and outlet flow paths are provided with respective openings in the bottom face of the body; in that at least a portion of the outlet flow path comprises a duct; and in that the thrust means comprises a propeller mounted within the duct.

Preferably, the inlet and outlet flow paths are parallel, but of opposite directions.

Preferably, the duct is formed with an outlet in the undersurface of a central section of the body.

Suitably, an adjustable flow regulator is provided adjacent the inlet of the inlet flow path. Typically, the flow regulator comprises a louvre assembly.

In one particular embodiment, the body is in the form of a wing having an angled face at at least one of leading and trailing edges thereof. Such face or faces may be provided by means of an additional wing profile attachment to the body.

Suitably, the apparatus is of simple box-like construction, being made from steel plate, with one ducted propeller unit per apparatus. The design is preferably such that

two or more units can be easily coupled together in different configurations for multiple jetting operations. In order to be able to operate in very shallow water and yet maintain a reasonable distance from the bed, the apparatus is designed with intakes on the underside that face downwards. Provided the apparatus is initially filled with water (primed) it can continue to operate when lifted partway above the waterline, since water will continue to siphon through the body of the apparatus and into the propeller duct. Adjustable opening louvre plates over the intakes provide protection from ingress of debris and also a means for preventing rotation of the apparatus (countering the propeller torque) when operating in single-jetting mode. More importantly, they also provide a means for controlling the rate of water flow through the propeller duct.

The propeller is driven by a high-pressure hydraulic motor, which is located axially within the duct. The use of a hydraulic motor is an integral part of the overall design of the apparatus, since it enables a very compact and light-weight construction (compared to the aforementioned Wing Dredger) and also provides for variable speed and direction control over propeller rotation. The apparatus can also be more easily fitted with the means to modify the behaviour of the jet: to create a straight-sided or wide-angle jet, as required.

The above and other aspects of the present invention will now be described by way of example only and with reference to the accompanying drawings, in which:

Figure 1 shows an oblique underside view of the exterior of an apparatus in accordance with the present invention.

Figure 2 shows an oblique topside view of the exterior of the apparatus of Figure 1.

Figures 3 and 4 show sectional views through the apparatus of Figure 1. Figure 3 is a vertical section on the long axis, and Figure 4 is a horizontal section at mid-level.

Figures 5, 6 and 7 show sectional views through one of the intakes to illustrate the louvre plates and the mechanism controlling the degree of opening of these plates. Figure 5 shows the louvre plates fully open (against the bar stop), Figure 6 shows the louvre plates half open (against the bar stop), and Figure 7 shows the louvre plates shut (with no flow through the intakes).

Figures 8 and 9 show, in diagrammatic form, the water-flow circulation through the apparatus of Figure 1 depending on the direction of rotation of the propeller. Figures 8 shows normal flow jetting, and Figure 9 shows reverse flow filling (priming).

Figures 10 to 13 shows various ways in which the apparatus can be suspended from a vessel and various ways in which multiple units can be coupled together.

Figures 1 and 2 show an embodiment of the apparatus of the present invention including a rectangular body or tank 10 of generally light-weight construction; steel plate being a suitable construction material. The dimensions of the tank, as shown, are in the ratio: length 3; width 2; height 1.5. It is envisaged that these dimensions would be represented by metres, however the overall size of the tank is not critical to the operation of the apparatus and may be any convenient size or, indeed, shape

To provide added stiffness to the construction, as shown in Figures 1 and 2, side plates 12, and top and bottom plates 13 and 14, are joined by angled plates 15. This has the added benefit that on the inside of the tank the lower sides slope inwards creating a partial hopper effect. Material carried in-board in suspension with the intake flow (see Figure 8) that might otherwise settle inside the tank, in the angle between the sides and base, is encouraged to slip down towards the intake and so be re-suspended by the intake flow.

Reference to Figure 3 shows that the hopper effect is completed by angled fillets 47 placed along the contact between end plates 16 and bottom plate 14 and between bottom plate 14 and central bulkhead plate 45.

Various attachment points are provided on the outside of the tank, as indicated in Figures 1 and 2. There are four corner attachment points 17 at each end, formed by the projections of end plates 16, and four centre attachment points 18, which comprise triangular plates 19 welded to angle plates 15. The position and orientation of triangular plates 19 correspond internally to bulkhead plate 45. Smaller triangular fillet plates 20 provide added lateral stiffness to each of the support points.

Referring to Figure 2, it can be seen that two hatch-covers 22 are provided on top of the tank that give access, via associated openings in top plate 13, to the inside of the tank. These hatch covers are of conventional construction, but are designed specifically to provide an air-tight seal to the tank when fully closed. Also on the top of the tank are two grab rails 23 that run along the outer long edge of top plate 13. These are formed of steel pipe and are attached at their two ends and at intermediate locations in such a way that there is communication between the inside of the tank and the bore of the pipes. Set onto the top of the grab rail pipes towards each end, are short, internally threaded, spigot pipes 24, into which non-return valves (not shown) can be screwed. The non-return valves are designed to allow egress (venting) from the tank of air and water, but not ingress. Their function and operation will be described later.

Also on the top of the tank and attached to top plate 13 by means of multiple bolts, is a circular plate 25. Circular plate 25, when removed, gives access to the inside of the tank for the purpose of removing the propeller duct unit. The circular opening in top plate 13 that is covered by circular plate 25 is, therefore, slightly larger in diameter than the widest lateral dimension of the propeller duct. Circular plate 25 is fitted with a rubber gasket designed to effect an air-tight seal.

Also formed centrally in circular plate 25 are three circular openings set out in triangular fashion, which provide penetrations for the three hydraulic hoses that connect to the motor (two high-pressure power hoses and one low-pressure casing

drain hose). Split flanges 26, formed of rigid plastic, and bolted to circular plate 25 over each opening, encircle each hose and provide an air-tight seal where the hoses enter the tank. Split flanges 26 also serve to secure the hoses at the point of entry to the tank, thus preventing any risk of chaffing of the hoses against metal edges. Split flanges 26 can be more clearly seen in Figure 3.

Completing the appurtenances on the top of the tank, as shown in Figure 2, is a small detachable stool-like structure 27, consisting of a circular ring supported by means of struts at a fixed distance above the top plate. The hydraulic hoses pass through the ring and are loosely supported in such a way that over-bending, or kinking, of the hoses at the point of entry into the tank is prevented.

Referring to Figure 1, the circular outlet 28 of the propeller duct can be seen to be centrally located on the underside of the tank. Also the position of the propeller 29, just inboard of the duct opening, can be clearly seen. It should be noted that there are no rigid obstructions (vanes, struts or other protrusions) in way of the propeller jet, within or below the outlet end of the duct.

Located either side of the propeller duct outlet 28, are two water intakes 30. These are rectangular in shape and are of such a size that one on its own would provide for unhindered flow of water into the propeller duct, when the propeller is rotating at full speed. Attached to the bottom plate 14 and extending vertically over each opening are three thick metal grill plates 31. These are designed to prevent large items of debris, or obstructions sticking up from the seabed, from penetrating the intakes. They are also designed to take the weight of the apparatus when the latter is placed on-deck or onto a hard-standing surface. If the apparatus were to be placed on a soft surface, wooden sleepers would be used to prevent the grill plates from penetrating into the surface.

Figure 1 also shows that immediately inboard of the intakes 30 are multiple louvre plates 32, which extend across each intake. These are designed to prevent ingress of

smaller debris that might otherwise pass between the thick metal grill plates 31. Each louvre plate has a hinge attachment to the bottom of the tank at either end, such that each plate is free to rotate about a hinge-line coincident with the bottom edge of the plate. A detail of this hinge attachment is shown in Figures 5 to 7.

Referring to Figures 5 it can be seen that a simple horizontal bar stop 33, supported at either end on pillars 34, allows adjustment of the amount of opening of the louvre plates 32. Each pillar 34 has a series of holes drilled into it to allow the bar to be secured at different heights above the base of the tank. As presently designed, adjustment of the amount of louvre plate opening has to be by hand, requiring man access through the hatch covers with the apparatus on deck. It is envisaged that in due course a remotely operated louvre adjustment mechanism will be adopted.

When the louvre plates are lying flat (Figure 7), the intakes are effectively closed, save for minor leakage at the edges of the plates. This leakage is useful in that during reverse circulation flow (see below) it allows any residual sediment that may have collected in the bottom of the tank to be flushed out. When the louvre plates are pointing nearly vertically upwards (Figure 5), the intakes are fully open, allowing unhindered flow to the propeller duct. When no water is being drawn through the intakes, self-weight causes the plates to fall shut and adopt the imbricate arrangement shown in Figure 7.

It should be noted that the louvre plates are set in such a way that they face in opposing directions over each intake. While this is of little consequence when the plates are fully closed or fully open, it will be appreciated that with the louvre plates at intermediate positions (Figure 6), water entering the intake is forced to do so at an angle, which will be opposed on the two sides. Opposed deflection of the intake water flow imparts a turning moment to the apparatus, which helps to counter any tendency for rotation in the opposite direction induced by the propeller. Needless to say, the direction of angling of the louvre plates has to be co-ordinated with the direction of rotation of the propeller.

Lastly, in referring to Figure 1, it should be noted that surrounding the outlet end of the propeller duct is a flange plate 35 directly welded to the bottom plate 14. Flange plate 35 has a series of tapped holes drilled into it. The purpose of the flange plate is to allow attachment of a flared nozzle, the function of which is discussed in PCT/GB2003/005030.

Reference to Figure 3 shows the inside of the tank in vertical section to illustrate the disposition of the propeller duct 36 and motor 37. The propeller duct 36 can be seen to have a vertical length approximately 2/3 the height of the tank, and to have a bellmouth 38 at the top (inlet end) to facilitate the inflow of water. Motor 37 is axially positioned in the duct with its shaft (not seen) facing downwards and the high-pressure hydraulic fluid ports (for attachment of the two high-pressure hoses 38) facing upwards. A side-tap on the motor (not shown) provides attachment for the casing drain hose 39 (see Figure 2).

Motor 37 is supported axially within the duct by means of collar 40 to which the motor is secured by a ring of axial bolts, and the collar is secured to the inside of the duct by means of angled fin plates 41. The fin plates are vertically set in order to present a limited surface area to the direction of flow and their edges are also chamfered to further minimise flow obstruction. There are five supporting fin plates 41, equally spaced; this number being purposely chosen to provide both a rigid axial support to the motor and an non-equal or non-multiple of the propeller blade number (four-bladed propeller): the latter being good engineering practise in terms of ducted propeller design. The arrangement of the fin plates can be better seen in horizontal section, in Figure 4.

The motor can be seen to taper downward at its front end, forming a smooth transition with the hub of the propeller 29. The smooth profile of the motor and propeller hub matches the shape of the duct, giving a uniform width of annulus between the motor and the duct.

The duct, complete with motor, can be detached from the tank and removed through the top of the tank. The duct has three rings 42 welded around its outer circumference. These are designed, partly, to maintain the ovality of the duct both during and following fabrication. The uppermost ring also gives added stiffness to the duct at the point of fixity of the angled motor support fin plates, while the lowermost ring also acts as a seating flange when the duct is installed into the tank. This lowermost ring has two holes drilled into it that act as stabbing guides for pegs 43 (indicated by small arrows) that stick up from a landing flange 44 on the bottom of the tank. The two upper rings also have holes drilled in them to enable the duct to be rigidly secured on either side to the central vertical bulkhead plate 45. Angled brackets 46, in pairs, provide the means for bolting the propeller duct to the bulkhead plate and can be seen in Figure 4.

Also visible in Figure 3 are the fillets 47, which complete the hopper-like form of the tank base around each intake, as can be better seen in Figure 4. The fillets may be of any suitable material, such as concrete, and may be removable or cast in situ.

Lastly, in referring to Figure 3, it should be noted that while bulkhead plate 45 only extends inwards as far as the propeller duct, it stretches the full height of the tank; and thus effectively divides the tank into two separate compartments below the top level of the propeller duct. Directly over the top of the propeller duct, however, there is free communication between the two halves of the tank.

The workings of the apparatus will now be briefly described by reference to Figures 8 and 9. In the first instance, it will be assumed that the apparatus is being operated in sufficient depth of water that the siphonic action is not required.

Figure 8 shows that when the propeller is rotating, such as to produce a downward jet of water, water is drawn through intakes 30; circulates through each side of the tank; enters the top of the propeller duct through bellmouth inlet 38; travels through duct 36

and is forced out through duct outlet 28. The reduction in pressure inside the tank caused by the rotation of the propeller (acting like an axial flow pump) causes louvre plates 32 to open as far as paired bar stops 33 will allow. Water is thus sucked upwards into the tank at a rate determined by the speed of rotation of the propeller and the degree of opening of the louvres.

Since all other points of ingress for water into the tank are sealed, the louvre plates provide an effective means for regulating (i.e. reducing) the flow of water through the propeller duct for any given speed of rotation of the propeller. The main reason for wanting to reduce the flow of water through the propeller duct is that the axial velocity of the jet is reduced compared to its swirl velocity and so the Jet Swirl Number is increased (see PCT/GB2003/005030 for a more detailed description of Jet Swirl Number). In propeller design parlance, a decrease in flow through the propeller disc is referred to as a reduction in propeller advance coefficient (J). One of the significant effects of this (as described more particularly in PCT/GB2003/005030) is that the behaviour of the jet is changed, making it more susceptible to breakdown.

When starting the apparatus in very shallow water an initial priming action may be necessary, which is illustrated in Figure 9. The propeller is initially rotated in reverse at slow to moderate speed. This has the effect of forcing water into the tank through the propeller duct. The louvre plates act as (slightly leaky) one-way valves preventing wholesale egress of water through the intakes. Air and then water are thus forced out of the top of the tank through the four non-return valves in vent holes 24. Once the tank has been filled with water and purged of air (indicated by continuous spouts of water from the holes 24) the motor rotation is quickly reversed to begin normal jetting operations, as explained by reference to Figure 8. This priming action can also be used as an effective way of cleaning (back-washing) residual sediment from the bottom of the tank; material being flushed out by the leakage flow that occurs through the gap between the ends of the louvre plates and the underside of the tank (see Figure 7).

Normal jetting, once established, can continue even with much of the tank out of the water, because the propeller creates sufficient suction head for water to siphon into the propeller duct. The fact that the intakes are placed on the underside of the tank also means that there is less likelihood of air being sucked in via a drain-hole vortex. Clearly, for this siphonic action to work effectively the emergent top of the tank has to be fully air-tight.

For most operations, where simple jetting of the bed is required, the apparatus would be suspended by one or two pairs of wires from a crane, or A-frame, mounted on a support vessel. Figures 10 to 13 show a number of possible support options, together with various ways in which several single-jet units can be coupled together to form multiple units. In Figure 10 a single unit is shown suspended by two wires 48. Loops of chain 49 with their ends attached to the upper corner points 17 provide a means for adjusting the roll and pitch of the apparatus. By shackling the wires to links on one or other side of the centre point of each loop, forward or backward pitch can be introduced. By adjusting the length of each chain independently, sideways roll can be effected. In this respect, operation similar to that described in U.S. Patent 6125,560 is achieved.

Single unit operation is intended primarily for pipeline (or cable) jetting work. For instance, where a pipeline laid on the seabed is required to be lowered below the bed for the purpose of increased protection. The ability to tilt the apparatus sideways is important, since by directing the tilted jet just under the pipe as the unit traverses along and adjacent to the line of the pipe, material can be displaced to the far side of the pipe to form a levee stockpile. The same material can then be used to backfill the trench by jetting from the opposite side with the jet tilted towards the stockpile and the trench. Note that a significant advantage of this jetting equipment over conventional pipeline ploughing equipment is that there is no mechanical contact with the pipe.

In Figure 11 two units are shown coupled together in-line and suspended in similar fashion, but with the chains 49 attached to the four upper centre attachment points 18. Because the separation of the wires and the attachment arrangement of the chains is identical to that for the single unit (shown in Figure 10) a double unit can be operated from the same vessel in exactly the same way as a single unit. It is a also a very simple matter to couple two units together in-line, by means of four high-tensile bolts passing through the four common corner attachment point holes 17.

A double in-line unit (or indeed a triple in-line unit, as shown in Figure 12) would be used primarily for bulk excavation and movement of material. This might include pre-sweeping of a corridor through sandwaves for the purpose of preparing a smoothed profile for laying a large diameter pipeline, or it might include removal of material from shoal areas in a navigation channel. Either way, material has typically to be removed in large quantities to an agreed level, and in the latter case the excavated material has to be deposited below the navigation depth. By operating two or more units in-line the jets act in concert to remove a swathe of material. Typically, the units would be tilted (pitched) in the direction of forward travel so that material is displaced in this direction. No sideways roll would be used, as the objective is to create a level surface.

Finally, Figure 13 shows two units coupled together in saddle fashion, metal struts 50 being used to cross-connect adjacent upper and lower attachment points (17 and 18) and achieve the desired angle of convergence of the jets. A similar means of suspension is used, as in the other sketches. Such a converging jet arrangement would be employed, for instance, where increased jetting energy was required for lowering a pipeline (or possibly exhuming an existing buried pipeline). The focussing of the two jets means that excavation energy is concentrated at the point of intersection of the two jets.

Advantages of the apparatus for the present invention include:

1. An improved ability (compared to U.S. Patent 6,125,560) to operate in shallow water for the purposes of carrying out underwater jetting excavation and movement of bed material. Said ability being achieved by means of a short propeller duct, housed inside an air-tight tank, with the primary water intakes on the underside of the tank and with the ability to carry out an initial priming operation wherein the propeller is reversed to induce filling of the tank.
2. An improved ability and greater versatility to operate in single- and multiple-jetting configurations, by coupling single jetting units together.
3. An improved ability to control and regulate the velocity of flow through the propeller duct and at its outlet end for the purpose of modifying the behaviour of the jet. Said control being exercised by adjusting the degree of opening of the louvre plates, which function like one-way valves.
4. An ability, stemming from point 3 and the use of various attachments (as discussed in PCT/GB2003/005030), to carry out very rapid excavation in a wide range of loose bed materials, with the attendant directional movement of the excavated material over long distances (100m's).
5. An ability, also stemming from point 3 and the use of various attachments (as discussed in PCT/GB2003/005030), to carry out excavation (albeit at a slower rate) in stiff clay materials that are otherwise not amenable to excavation by means of low-pressure water jetting.
6. An ability, equal with U.S. Patent 6,125,560 to operate the apparatus from a support vessel by means of a wire suspension system wherein the attitude of the apparatus can be adjusted in terms of both pitch and roll. Said capability being used for the purpose of sideways displacement of material (such as for pipeline jetting) and for forward displacement of material (such as for pre-sweeping and sediment management operations).
7. An added benefit, further to point 3, that the said louvre plates also provide a means for preventing access of debris into the propeller duct.
8. An added benefit, further to point 3 and point 7, that the said louvre plates when half open also provide a means for preventing rotation of the apparatus by countering the turning moment induced by the propeller.

9. The added benefit, further to point 7, wherein thick grill plates over the intakes protect from ingress of coarse debris and penetration of seabed obstructions. Said grill plates also provide a means for supporting the apparatus when not in use.
10. A simple body shape that is strong, light-weight and functional (in terms of forming an air-tight sealed tank), that is, in effect, self-cleaning by having a hopper-like base form, that has attachment points strategically placed to enable the body to be suspended from wires and chains and coupled to like bodies in different configurations for the purpose of multiple jetting.
11. A simple means for installing and removing the propeller duct, i.e. for maintenance purposes, and to enable said propeller duct to be used in other propeller jetting embodiments (as described in PCT/GB2003/005030).
12. The added benefit, further to the self-cleaning ability noted in claim 10, of using the priming action, noted in point 1, as a further means for cleaning (back-washing) the inside of the tank.